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ANALYSIS OF SELECTION OF WIND TURBINE AS A SOURCE OF ADDITIONAL ELECTRICITY IN THE TOURISM AREA BANYAK ISLAND, INDONESIA

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Abstract

The Banyak Island in Aceh Singkil-Indonesia have been developed as a tourism destination that has great potential to bring in regional foreign exchange. Electricity consumption in this area is only supplied by using diesel power plants. The development of renewable energy sources for power generation is very prominent which is carried out to overcome the reduced availability of fossil energy sources. In addition, the burning of fossil energy sources will have an impact on environmental pollution and the production of gas emissions. Environment due to the use of fossil-based electricity, it is necessary to develop alternative renewable energy based on wind turbine. To implement wind turbine in the Banyak Island, a study of the potential of wind turbine resources must be carried out. The method used in this research is quantitative type with data processing and descriptive approach. Analysis of wind speed data in 2020 in the tourist area of Banyak Island was carried out with the Weibull distribution equation, parameters k = 2.935758902 and c = 8.921518. The data obtained were analyzed using analytical methods to calculate wind energy potential and its conversion into electrical energy. After analyzing the wind speed data in 2020 in the Balai island tourist area with the Weibull distribution equation, the parameters k = 2.935758902 and c = 8.921518. Through capacity factor analysis, it is known that small-scale wind turbines produce energy of 115,154 kWh/year per turbine. The data obtained were analyzed using analytical methods to calculate wind energy potential and its conversion into electrical energy. After analyzing the wind speed data in 2020 in the Balai island tourist area with the Weibull distribution equation, the parameters k = 2.935758902 and

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Index Terms: Descriptive Approach, Weibull Distribution, Wind Power Generation

I.INTRODUCTION

Indonesia is the country with the largest energy consumption in the Southeast Asia region and ranks fifth in the Asia Pacific in primary energy consumption, after China, India, Japan and South Korea. High GDP growth, reaching an average of 6.04% per year during the 2017-2050 period, is expected to further encourage the increase in Indonesia's energy needs in the future [1]. Energy consumption in Indonesia is still dominated by the use of coal by 58 percent and gas by 19 percent which are fossil resources [2] PLN data in 2016 showed that Indonesia's per capita electricity consumption at that time reached 956 kWh per capita. 7,970 kWh per capita. From these data it can be concluded that the indicators of a country's economic progress can be measured by energy consumption per capita. The level of electricity consumption in Indonesia continues to show a significant increase every year. Capita [3] By looking at the data on energy use that continues to increase, it will drain fossil resources more quickly, therefore the development of renewable energy needs to be done to overcome the problem of depleting fossil energy sources. [4] [5] Currently, the use of renewable energy in Indonesia is still around 6.8%, and the government continues to encourage development referring to the 2010-2025 National Energy Management blueprint and National Energy Policy. , geothermal, wind energy, biomass energy, and water energy. One of the environmentally friendly alternatives is wind power which is the main focus of this research. ,15 m/s [6].

Previous research that discusses the potential of renewable energy using wind power in Indonesia has been widely carried out. if wind turbines are developed as alternative energy on the island [7] Research on the potential of wind energy in the city of Pontianak shows unsatisfactory results because the research was conducted in plantation areas with lots of trees [8], as well as research in Sulawesi and Maluku, there are four locations that have the potential to be developed as wind energy in the region [9]. The problem of electricity availability in small islands has been going on for a long time where the electricity supply is generally generated from diesel generators which has an impact on community activities. The Banyak Island as the Outer Islands of Aceh Singkil Regency is one of the tourism icons that will be developed. However, electricity consumption is still supplied by diesel power plants. Therefore, an in-depth study is needed in dealing with other electrical intakes. Renewable energy sources can contribute to a sustainable power generation system. potential without determining the exact location and placement, especially in the special islands of Aceh.

Therefore, a study to explore the potential for wind speed as a power plant in the archipelago, especially in tourist areas, is very necessary. Likewise, there are many considerations that combine areas / areas that have the potential for wind and provide appropriate placement decisions based on several social, economic, environmental and technological criteria in Indonesia. Therefore, it is important to use good and comprehensive decision-making methods to determine the appropriate location and placement. This information can also be used to

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develop policies related to efficient spatial planning and location of power plants from economic, technological, social and environmental aspects. The results of this study can be useful for the Economic Planning Unit, the Ministry of Environment and the Ministry of Energy and Mineral Resources of the Republic of Indonesia in planning renewable energy programs that are efficient, environmentally friendly and do not damage social norms. Furthermore, this study aims to improve the living standards of many Pulau Banyak people who develop the tourism sector as income. In the Banyak Island area, total energy consumption continues to increase by 6% per year. The current energy era is very demanding and requires the effective use of non-conventional energy resources. Wind energy is one of the most promising alternatives. In this study, a quantitative type method with data processing and a descriptive approach will be used to analyze wind energy potential and determine the appropriate type of wind turbine to be applied in the Water Front Area of Balai Kepulauan Men Banyak Island. the amount of kinetic energy, the potential for wind energy and its conversion to electrical energy. The final results of this study can provide a complete picture of the potential of wind resources as power plants in the Water Front Area of Pulau Balai Pulau Banyak. This information can also be used to develop policies to related agencies such as the Tourism Office and the Ministry of Energy and Mineral Resources in spatial planning and efficient power plant locations from economic, technological, social and environmental aspects. Furthermore

II.LITERATURE REVIEW

A. Renewable Energy

Position figures and tables at the tops and bottoms of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be centered below the figures; table captions should be centered above. Avoid placing figures and tables before their first mention in the text. Use the abbreviation "Fig. 1," even at the beginning of a sentence.

Renewable energy can be defined as energy that can be quickly reproduced through natural processes. Renewable energy includes water energy, geothermal, solar, wind, biogas, biomass and ocean waves. with free, minimal waste, does not affect the global temperature of the earth and is not affected by rising fuel prices [10]. According to the Ministry of Energy and Mineral Resources (DESDM) Renewable energy is energy that can be renewed and if managed properly, these resources will not run out [11]. Utilization of renewable energy in the world and in Indonesia is still not optimal even though the potential is very much, for example the potential for wind energy [12]. The total accessible wind energy is close to 10 million MW which can provide 35% of the total world demand. Global installed wind energy capacity reached 432 gigawatts (GW) at the end of 2015. By 2013 it was around 35.6 GW and it is estimated that by the end of 2019 the cumulative installed capacity will reach 666 GW [13].

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Indonesia is a country that has enormous natural electrical energy potential, one of which is wind. Wind Potential Based on Wind Speed in Indonesia is divided into 3 groups, namely [14]:

1. Group I: Locations with an average wind speed of 1 - 2.5 m/s, the power generated is between 0-200 kWh/m2 a year. The wind conditions are not good to be utilized.
2. Group II: Locations with an average wind speed of 2.5 – 4 m/s, the power generated is between 201 – 1000 kWh/m2 a year.
3. Group III: Locations with an average wind speed of 4.5 - 12 m/s, the power generated is more than 1000 kWh/m2 a year.

The process of utilizing wind energy is carried out through two stages of energy conversion, first the wind flow will move the rotor (propeller) which causes the rotor to rotate in harmony with the blowing wind, then the rotation of the rotor is connected to a generator, from this generator an electric proverse current is generated. The energy starts from the kinetic energy of the wind into the energy of the rotor motion and then into electrical energy [15] [16]. The terms and conditions of wind speed can be measured by measuring wind speed and direction.

Table 1 Beaufort scale Wind Speed Level

Class	Speed	Natural Conditions on Mainland
1	0 – 0.02	
2	0.3 – 1.5	Calm wind, smoke straight up
3	1.6 – 3.3	Smoke moves in the direction of the wind
4	3.4 - 5.4	The face feels the wind, the leaves sway slowly, directions moving wind
5	5.5 – 7.9	The face feels the wind, the leaves sway slowly, directions moving wind
6	8.0 – 10.7	Tree branches sway, and flags fly
7	10.8 – 13.8	The tree branches sway, the water will make small waves
8	13.9 – 17.1	The tip of the tree bends, the wind blows in the ear
9	17.2 – 20.7	Can break tree branches, feels heavy when walking against wind direction
10	20.8 – 24.4	Can break tree branches, Houses can fall
11	24.5 – 28.4	Can knock down trees and inflict damage
12	28.5 – 32.6	Inflicts heavy damage
13	32.7 – 36.9	Tornado

The level of wind speed, wind speed classes and conditions that can be seen around when the wind is in a certain class can be seen in table 1 above [15] [17]. While wind speeds above class 8 are dangerous and can cause damage to the turbine.

B. Wind Turbine Parameters

Wind turbine parameters are needed to determine the estimated power output of the wind turbine [18]. The wind turbine power curve is obtained from 3 aspects, namely cut-in speed, rated wind speed and cut-out speed of the turbine used. Change. Wind power density is the power contained in the wind per unit area. The wind power density category can be seen in the table below [19].

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Table 2 Categories of Wind Power Density 50 Meters High

Wind Energy Class (Wind Power Class)	Wind Power Density (watts/m2)	Energy Potential
1	0-200	Very bad
2	200-300	Bad
3	300-400	Enough
4	400-500	Well
5	500-600	Very good
6	600-800	Tree branches sway, and flags fly

Capacity factor is a value that shows the magnitude of the ratio between the actual energy outputs of a turbine in a certain location compared to the energy that can be produced by a turbine. The higher the value of the resulting capacity factor, the turbine will produce energy per year which is closer to the rating of the wind turbine. Therefore, if there are various turbine options for a location, the turbine that will be used is the turbine with the highest capacity factor [20] [17]. The types of wind turbines based on rated capacity, can be seen in table 2 below [21] and quoted by [17].

Table 3 Categories of Wind Turbines Based On Rated Capacity

Turbine Type	Rated Capacity
Micro	<1 kW
Small	<100kW
Currently	100kW – 1MW
Big	>1MW

Based on the IEC 61400 standard, the wind turbine category based on the maximum annual average wind speed can be seen in table 4 below.

Table 4 Categories of Wind Turbines Based On Wind Speed

	Average Wind Speed Annual (m/s)
I (High Wind)	10
II (Medium Wind)	8.5
III (Low Wind)	7.5
IV (Very Low Wind)	6

III. EXISTING CONDITION

A. Maps and Geography

The Aceh Aceh region is located at the northernmost tip of the island of Sumatra with an area of 58,357.63 km2. limited by:

1. The Strait of Malacca to the North and East
2. North Sumatra Province in the South
3. Indonesian Ocean in the West

The research location was on the Banyak Island in Aceh Singkil Regency, Aceh Province.

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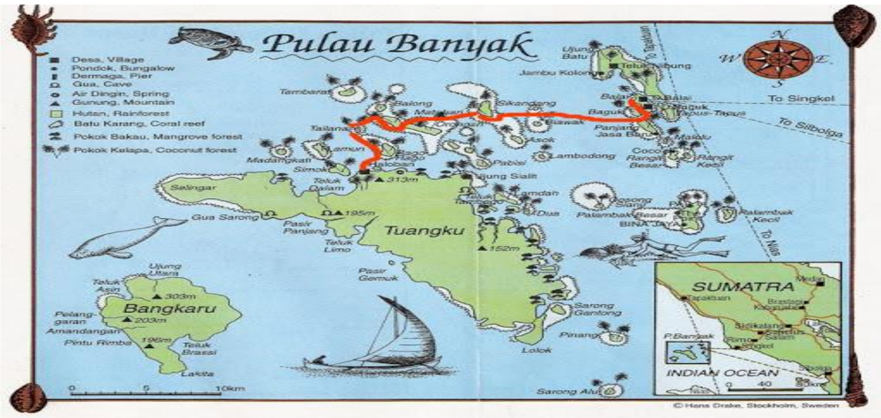
Fig. 1. Map of Banyak Island



The geographical location of the Banyak Island area is listed in Table 5 below.

Table 5 Many Island Border Areas

No	Area	North	South	East	West
1	Many Island	Indonesian Ocean	Indonesian Ocean	Singkil Kecamatan District	Simelue County
2	West Many Island	Indonesian Ocean	Indonesian Ocean	Pulau Banyak District	Indonesian Ocean

B. Supply and consumption of electrical energy

The supply of electrical energy in the Banyak island area is entirely from Diesel Power Plants. The data on the currently installed diesel power plant are as shown in Table 6.

Table 6. Availability of Diesel Power Plants in the Banyak Island Region

No	Location / Brand	Power (kW)		Peak Load More (kW)	Production (kWh)		Fuel (liter)		
		Installed	Power Capacity		Clean	Dirty	BBM More	Bio HSD	Bio Fame
	PLTD The Balai island								
1	MTU	400	270	270	96920	96920	31999	22399	9600
2	MTU	528	280	280	117910	117910	38908	27235	11673
3	DEUTZ	250	-	-	-	-	-	-	-
4	DEUTZ	250	150	150	-	-	-	-	-
5	MTU	528	-	-	-	-	-	-	-
	Amount	1956	700	700	214830	214830	70907	49634	21273
	PLTD Kuala Baru More								
1	MAN	312	160	160	62019	62019	18243	12770	5473
2	DAF	117	-	-	-	-	-	-	-
3	DAF	140	90	90	15941	15941	5109	3576	1533
4	DAF	117	90	90	-	-	-	-	-
5	DAF	140	-	-	-	-	-	-	-
6	DAF	140	90	90	10479	10479	3394	2375	1019
	Amount	966	430	430	88439	88439	26746	18721	8025
	PLTD Haloban								
1	DEUTZ	40	35	35	-	-	-	-	-

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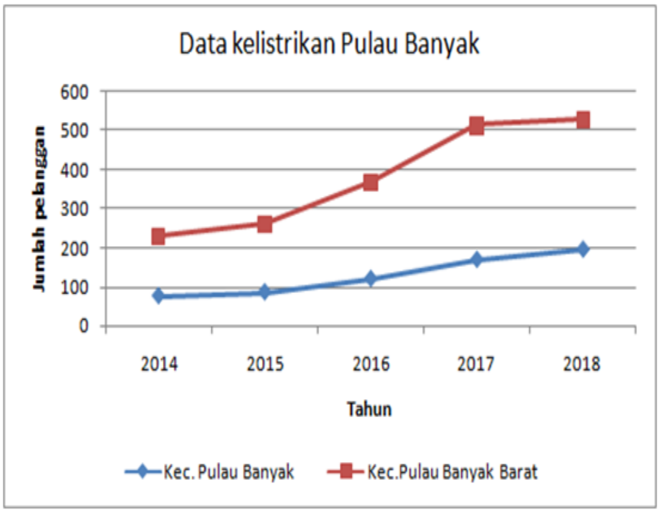
2	DAF	117	90	90	23696	23696	8764	6134	2630
3	DEUTZ	40	25	25	-	-	-	-	-
4	DAF	117	90	90	21297	21297	7883	5518	2365
5	DAF	117	90	90	22639	22639	8390	5873	2517
6	DAF	-	-	-	-	-	-	-	-
	Amount	431	330	330	67632	67632	25037	17525	7512

Fig.2. Electricity customers for Pulau Banyak area



According to data from the Central Statistics Agency, electricity consumption in Pulau Banyak has increased from year to year [22]. The increase in energy consumption is inseparable from economic growth which is also getting better. The increase in energy consumption is also influenced by other factors, namely the increase in population and also the addition of new families that allow the construction of new houses that require electricity. Increasing population growth and the economy affect the amount of electricity consumption. It can be seen in Figure 2 that the electricity consumption in Pulau Banyak continues to increase [22].

By looking at the data from the graph above, energy use in the future will continue to increase [3]. The Banyak Island is an archipelago that has many coastlines. This resource appears to offer great potential for developing wind power capacity.

C. The Balai Island Wind Energy Source Situation

The data in this study were obtained from the use of secondary data that had been collected by the NASA POWER Data Access Viewer. The data obtained is in the form of a time-series format containing data on wind speed and temperature measurements carried out at a measurement elevation of 50 meters. Available data, with a range from January 2020 to December 2020. The data for the wind turbine power curve to be used is obtained from the data sheet provided by the turbine manufacturer. By taking the average value of the wind speed that blows for one hour.

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Table 7. Summary of Wind Speed and Temperature Data In 2020

No	Name	Average wind speed 50 (m/s)	Temperature (^{0}C)
1.	January	9.83	26.1
2.	February	6.68	26.01
3.	March	8.92	26.52
4	April	7.37	26.2
5	May	7.96	26.52
6.	June	8.4	25.58
7.	July	9.84	25.59
8.	August	8.7	25.67
9.	September	8.13	25,24
10.	October	7.23	25.23
11.	November	6.9	25.55
12.	December	5.6	25.3
	Average	7.96	25.82

The average wind speed value every month is always above the range of class 4 (7.0 – 7.5 m/s). 5 (7.5 – 8.0 m/s). The average value of air temperature every month is 25.82 C. Temperature data is needed to determine the average density of air at the measurement location. Land cover index data 0 at selected locations ranged from 0.3 to 0.5. For calculation purposes, class 3 value will be used, namely 0 of 0.4. flat. The average value of air temperature per month is 25.82^{0}C as shown in table 8 below. Temperature data is needed to determine the average density of air at the measurement location. Has been selected which is in the range between 0.3 to 0.5. For the purposes of the calculation will use the value of class 3, namely 0 of 0.4. The terrain is very rough and uneven

Table 8. Monthly air temperature data in 2020 (^{0}c)

No	Month	Temperature (^{0}C)
1	January	26.1
2	February	26.01
3	March	26.52
4	April	26.2
5	May	26.52
6	June	25.58
7	July	25.59
8	August	25.67
9	September	25,24
10	October	25.23
11	November	25.55
12	December	25.3
Average		25.82

IV. METHODOLOGY

First, a theoretical meta-analysis and consideration of the potential of wind power plants will be carried out. Then look for secondary data related to wind speed as the main potential of the

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relevant agencies. And experts to provide insight into general rules, and to verify interrelated dimensions for the framework.

The location of this research was carried out in the Water Front Tourism Area of The Balai Island, Aceh Singkil Regency, Aceh Province with coordinates 02° 18' 43.32" N - 97°24' 22.68" E. This research activity begins with studying some literature from previous studies related to the study of wind potential for power generation. in this study is to use a quantitative type by processing the data obtained. Analysis and data processing is carried out to determine the technical parameters and economic value as well as the potential for wind energy that can be converted into electrical energy in the Water Front Tourism Area of The Balai Island. The variables observed in this study were as follows:

1. Wind speed distribution.
2. The output of the turbine is based on the specifications of the selected turbine.

V. DISCUSSION

After obtaining the above data, the following parameters are obtained:

1. Average speed per year (v) elevation 50 m = 7.96 m/s
2. Average temperature per year = 25.82 C
3. Land cover indexes ($\boldsymbol{Z0}$) = 0.4 (Class 3)
4. Wind speed class = 5

Based on the data above, the research location is considered to have wind potential that can be used for power generation because the category of average wind speed per year is in class 5. This meets the requirements between classes 3 to class 8, category wind power for the purpose of generating electrical energy.

Analysis of technical parameters of wind energy is needed to determine the potential of wind energy at the selected location by using Weibull parameter analysis.

D. Wind Energy Parameters

Weibull distribution equation is used to model wind speed data. As for the Weibull distribution equation, there are several parameters needed, namely the shape parameter (k) and the scale parameter (c).

$$\mathrm{k} = \left(\frac{\sigma}{\mathrm{v}}\right) - 1.086 \,. \qquad (1)$$

Parameter (v) = 7.96 m/s. The value of the standard deviation (σ) is obtained from the wind speed data = 2.952781507, then the k value is obtained, namely:

$$\mathrm{k} = \left(\frac{2.953}{7.96}\right) - 1.086 = 2.936. \qquad (2)$$

After obtaining the value of k, the scale parameter value (c) will be obtained, with the following equation:

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$$\frac{c}{v} = \left(0.586 + \frac{0.433}{k}\right)_k^{-1} \quad . \qquad (3)$$

$$c = 8.922922 \quad . \qquad (4)$$

er the two parameters are obtained, the data from the wind speed in 2020 can be represented into the Weibull equation, namely,

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right]. \qquad (5)$$

$$f(v) = \frac{2.936}{8.922}\left(\frac{v}{8.922}\right)^{2.936-1} \exp\left[-\left(\frac{v}{8.922}\right)^{2.936}\right] \qquad (6)$$

After getting the parameters above, the value of the wind power density that we get at a height of 10 meters can be corrected through the following equation:

$$WPD = \frac{1}{2}\,(c)^3 \rho r \left(1 + \frac{3}{k}\right) = 424.97751/2\ \ (c)\text{^}3\ \rho r(1 + 3/k) = 424.9775. \qquad (7)$$

is the average density of air per year, which is 1.184 kg/m3. The wind power density value above shows the wind power density in an area of 1 square meter at a height of 50 meters. 50 meters of 424.9775 Watt/m2.

E. Selection of Wind Turbine Used

The selection of the wind turbine power curve is needed to determine the estimated annual energy output that can be produced from a location, if a wind turbine is installed. Wind turbine manufacturers will generally provide data sheets containing specifications of the wind turbines they produce in the form of turbine name, turbine class, hub height, turbine power curve and turbine electrical specifications. The specifications of the wind turbine need to be looked at, especially on the, and of the wind turbine to choose the best wind turbine to use. (Speed at which the turbine generates maximum power) close to yearly from a site of 7.96 m/s is needed to obtain a turbine that produces maximum energy for one year. Class III turbines are the most suitable wind turbines with an average wind speed of 7.96 m/s according to IEC 61400 standards and the Danish Wind Industry Association. categorized as Small Turbine, because the rated power capacity of this turbine is 20 kW. This turbine has the following specifications:

1. Number of Blades: 3
2. IEC Turbine Class: IIIa
3. Turbine type: Horizontal axis wind turbine
4. Rated power: 20 kW (Small Wind Turbine
5. Hub Height: 17/24/30/36 meters
6. $\boldsymbol{Vcut{-}in}$: 2.8 m/s
7. $\boldsymbol{Vrated}$: 7.5 m/s
8. $\boldsymbol{Vcut{-}out}$: 20.0 m/s

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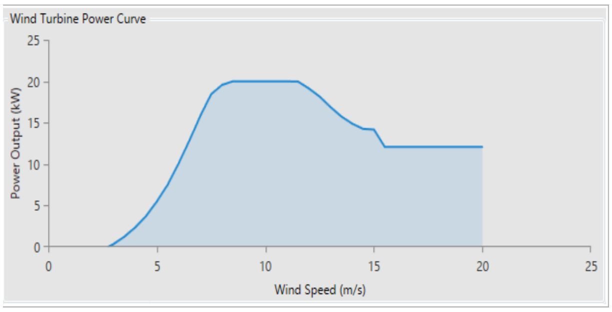
9. Output Voltage: 400V AC / 50Hz
10. Turbine diameter: 15.8 meters
11. Lifetimes : 20 years

Fig. 3. Eocycle EO20 20 kW . Wind Turbine Power Curve



In figure 3 above can be seen the power curve of the wind turbine used for this study. This turbine was chosen because of the specifications provided by the manufacturer where

$Vrated$ turbine of 7.5 m/s whose value is close to (7.96 m/s) measurement location and according to turbine class IIIa classification. In addition, this turbine has $Vrated$ the lowest is at a speed of 2.8 m/s.

F. Wind Turbine Power Calculator

This research uses software assistance provided by the Danish Wind Industry Association to find the annual energy output produced. In this software, several inputs are needed to determine the turbine energy output per year that will be produced, the parameters are as follows:

1. Weibull parameters are shape (k) and scale (c) parameters
2. Location average temperature
3. Land Cover Indexes
4. Turbine specifications, in the form of tower diameter and height
5. Turbine power curve

The output generated from the Wind Turbine Power Calculator Program by the Danish Wind Industry Association is:

1. Rotor power output (in Watts/m2 of rotor area)
2. Energy output (in kWh/m2 per year)
3. Energy output (in kWh per year)
4. Capacity factor (in a year)

Simulation Results with Wind Turbine Power Calculator

Simulation with the Wind Turbine Power Calculator program is used to find the annual energy output at an altitude of 50 m/s. This is done after getting the parameters required by the program.

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The first step is to enter the Weibull parameter value of the location. According to the calculations that have been done previously, the value of the location Weibull parameter is k = 2.935758902 and c = 8.921518. Average temperature value per year = 25.82 and C, land cover index ($\boldsymbol{Z0}$) = 0.4. Parameters k and c are useful for modeling wind distribution in the selected location, while temperature and land cover index are needed to obtain air density values and calculate wind speed at altitudes other than 50 m altitude calculations.

The second step is to enter the turbine parameter values that are used in the form of (20 kW), -$\boldsymbol{in}$ (2.8 m/s), -$\boldsymbol{out}$ (20 m/s), (20 m/s), and the height of the hub. Turbine Used (36 Met 36 Met

This step has the words "Note: Hub height differs from wind measurement height". Is the height the turbine will operate at? After doing calculations with the help of the Wind Turbine Power Calculator program, the results show that in a year the 20 kW Eocycle EO20 turbine produces 115,154 kWh of energy/year.

VI. CONCLUSION

The average wind speed in the many island hall tourism areas is of 7.96 m/s and wind power density of 424.9775 Watt/m2 (50 meters elevation). This indicates that the wind energy in the area can used to generate electrical energy through the use of small wind turbines (class III). Through the use of small wind turbines (class III) energy is generated of 115,154 kWh/year per wind turbine.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

A.H.: Conceptualization, methodology, formal analysis, writing original draft, M.S.; supervision, resources, project administration, W.V.; writing—review and editing, project administration, validation, M.D.; writing review and editing, project administration, validation. All authors have read and agreed to the published version. Of the manuscript

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